ARMY RESEARCH LABORATORY

TED—Turbine Engine Diagnostics

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13. ABSTRACT *(Maximum 200 words)*

TED (turbine engine diagnostics) is a diagnostic expert system to help the M1 Abrams' mechanic find and fix problems in the AGT1500 turbine engine. TED was designed and built by the U.S. Army Research Laboratory and the U.S. Army Ordnance Center. Limited fielding was begun in July 1994 to selected National Guard units, with eventual fielding to 28 National Guard units. Active units of the U.S. Army will receive TED in January 1996. Several foreign countries are expected to use TED for their M1 tank maintenance. TED was designed to provide the apprentice mechanic the ability to diagnose and repair the turbine engine like an expert mechanic. The U.S. Army Ordnance Center has estimated that TED will save more than $8 million annually by enhancing the M1 mechanic's diagnostic capabilities.

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1. Introduction

The Gulf War confirmed what the U.S. Army armor community realized long ago— the M1 Abrams main battle tank epitomizes lethality and survivability on today's battlefield. Unfortunately, there is a negative corollary, which is well known to the Army logistics community: the M1 is expensive to operate, support, and maintain. While many Army organizations are responsible for ensuring operational readiness of the fleet, it is the direct support (DS) mechanic who ensures the U.S. Army's new maintenance philosophy to **Fix Forward.** Combined with the Army's downsizing and skill consolidation efforts, the tasks of the DS mechanic are becoming increasingly more difficult. He is being asked to do more with less.

Recognizing these facts, the U.S. Army Ordnance Center (USAOC), in conjunction with the U.S. Army Research Laboratory (ARL), has focused research efforts to provide the DS mechanic with new maintenance capabilities. The project began in 1991, with the goal of providing the DS mechanic the best possible diagnostic and maintenance tools for the M1 turbine engine. The result of the combined effort is the development of a diagnostic expert system, known as TED (turbine engine diagnostics). TED assists the DS mechanic in effectively diagnosing and repairing the M1 Abrams turbine engine. Although TED is still an ongoing project, with final delivery due in January 1996, the National Guard Bureau has asked for early fielding of the completed modules. This fielding to National Guard units began in July 1994 and continues.

2. Background

By 1991, many factors were converging toward the need for a better maintenance system for the M1 turbine engine. The USAOC, responsible for maintaining all Army ground vehicles, asked ARL to join in a collaborative effort to improve M1 turbine maintenance.

2.1 Turbine Engine Maintenance Costs

The M1 Abrams tank is the Army's main weapon system, with more than 7500 tanks fielded to active and reserve units. The AGT1500 turbine engine takes the biggest slice of the maintenance budget. For instance, one study concluded that "the maintenance cost of the AGT-1500 engine represents the largest portion of the Army AGT-1500 operation and support (O&S) costs. These costs are $95.00 per operating hour (Textron, 1988)." Another study determined that in 1 year, out of 1 group of 360 engines evacuated to depot, 39% of them were reported as "no evidence of failure" (NEOF). The NEOF condition means that an engine was pulled from the tank, sent back to the depot for repair, but the depot determines there is nothing wrong with the engine. The unnecessary cost related to NEOF conditions was estimated at $18.2 million annually (Textron, 1989).

2.2 Maintenance Doctrine

Maintenance in the Army is accomplished at as many as four levels. The first is called organizational or unit level. This is company level maintenance. Items that cannot be fixed at the company are sent to the next level, called direct support. Direct support is usually at brigade or battalion. The next level above direct support is called general support (GS). This would normally be at division. The final level is called depot. For the AGT1500 turbine, there is often no general support maintenance. Engines that cannot be fixed at DS are sent to depot, and depot is usually in the U.S. (See Figure 1.)

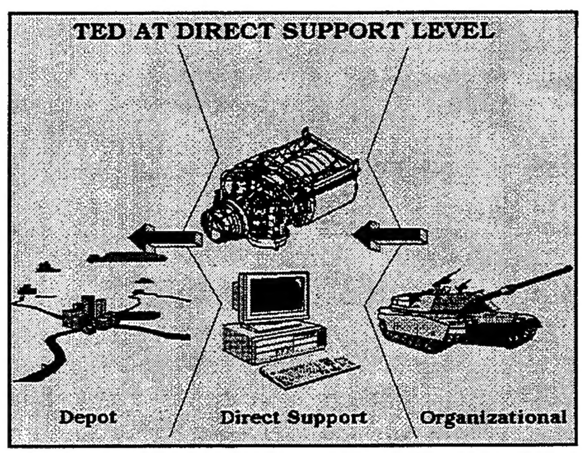

Figure 1: Maintenance-Level Military Structure

The TED project focused on DS-level maintenance for several reasons. First, the DS shop determines whether an engine should be sent to depot for repair, and this decision is expensive (~ $450,000 per engine). Second, the DS shop recently under went a major change in maintenance doctrine. Previously, when an engine failed at organization, the entire tank was evacuated to the DS unit for repair. Under the new

doctrine, when an engine fails, it is pulled from the tank and sent to DS. The tank hull remains at the unit, a new engine is sent forward, and the tank is quickly returned to full operational status. However, at the DS shop, without the tank, there was no way to start the engine. So new equipment, called the ground hop support set (GHSS), was designed and fielded to the DS shop. The GHSS replicates the missing functions of the tank: fuel, battery, driver's instrument panel, and electronic control unit (ECU). New maintenance procedures and new manuals were necessary to accompany this change.

Third, the DS shop has now been authorized to perform repairs previously done at GS or depot. This new maintenance concept is called **Fix Forward.** The new DS organization was initially called DS Plus to distinguish it from the original DS concept. The "Plus" has now been dropped. Under the new DS concept, the mechanic can now perform repairs previously not authorized. Along with the new authorized tasks come new tools previously available only at higher maintenance levels and new lists of spare parts that can be ordered at the DS level. There are no manuals for the new DS tasks.

2.3 Free Spare Parts

In the past, spare parts were free! If you were a company commander, and one of your tanks failed, it was fixed for free (as far as you, the commander, were concerned). Today, as that same commander, you are billed for your maintenance costs. The new doctrine is called stock funding of depot-level repairables (SFDLR), and the hope is that it will reduce overall maintenance costs, without adversely affecting unit readiness. Fortunately, the Army realized that SFDLR alone, without better maintenance aids for the mechanic, was not the final answer to reducing high maintenance costs.

2.4 Computers on the Battlefield

The Army is supplying computers to its mechanics. These computers are part of the Army common hardware, and are called the contact test set (CTS) III. CTS III is a DX-33 MHZ or DX-50 MHZ 80486 processor that employs 8 megabytes (MB) of RAM and either a 200- or 500-MB hard disk drive. It is capable of running either the SCO Unix Operating System or Microsoft DOS 6.2 with Windows 3.1. The goal is to field CTS III to every team of mechanics as part of the GHSS.

2.5 Paperless Battlefield

As computers become more prolific and handle more data and information, the concept of the digital battlefield has become more popular. The idea is that all information will be in digital format and will be stored, processed, and distributed by computers. Thus, the need for paper-based information is at least lessened and perhaps eliminated. For the mechanic, this means that all information currently available in paper format in the technical manuals (TMs), may soon be available in digital format on floppy disks, CD-ROMs, or on a removable hard drive. The goal of putting computers in the field is a reality; the goal of the paperless Army is not quite so near.

2.6 The M1 Forever

The M1 tank will remain in the Army inventory for a very long time. There are no plans or funds to replace the M1 within the foreseeable future. The reserve units are just now retiring their M60 tanks and are switching to M1s. It is likely that the reserve units will keep their M1 tanks for at least another 15 years.

3. TED History and Timetable

The TED program started in 1991 at the USAOC as an effort to seek solutions to some of the maintenance problems the Army was having with its equipment. ARL joined the program in the summer of 1991 as knowledge engineers and technical advisors, with the USAOC supplying subject matter experts (SMEs) to provide the expert diagnostic knowledge and to guide the development direction of the system. The USAOC also supplied engines and soldiers as needed to test the new software being developed.

The first TED prototype was ready by January 1992. For the next 18 months, existing modules were expanded and new modules were begun. By August 1993, the program was sufficiently developed to warrant formal testing. The first formal field test was conducted in August 1993. Section 8 contains the details of that test.

In January 1994, Project Manager-Abrams (PM-Abrams), the primary proponent for the Abrams tank,

met with members of the TED team. Two crucial questions were discussed: a) Would the TED program succeed?, and b) If so, how long would it take to finish? All agreed the project would succeed, and a target date of completion of January 1996 was given. With that, PM-Abrams decided to field TED in January 1996 to all active DS units with M1 tanks. In addition, further production of paper manuals for the AGT1500 engine was halted. The decision was made that TED would be the diagnostic system for the M1 turbine engine.

In March of 1994, the National Guard Bureau asked to have TED for its National Guard units as soon as possible. They wanted TED **before it was finished**, reasoning that even a partial TED would save them maintenance dollars. Fielding to the first two National Guard units (Georgia and Tennessee) began in July 1994. (Note that TED saved both states roughly $50,000 in its first 2 days of operation.) The National Guard Bureau continues to field TED at the rate of 2 to 3 states per month, until all 28 states with M1 tanks have the TED software.

As mentioned above, the Army will field TED in January 1996 to every active M1 DS unit (approxmately 200 sites). At least two foreign countries have agreed to use TED for their M1 DS engine maintenance.

4. Approach

The TED programmers quickly established some important project guidelines that remain in effect today.

4.1 Establish and Maintain Communication.

Programmers and SMEs do not speak the same language. Programmers talk of frames and objects, CARS and CDRS. M1 mechanics talk of inlet guide vane (IGV) angles, and of rotational variable differential transformers (RVDTs). Each needs to learn some of the other's language, but the main effort is on the programmer to learn the language of the mechanic.

4.1.1 Learn What the User Does.

The best way to do this is to observe the user in his environment. The TED team attended and videotaped classes for M1 mechanics. This produced three important benefits. First, it quickly immersed the programmers into the language of the mechanic. The IGV is located in front of the engine and the angle determines how much air gets through to the turbine blades. Second, it gave an accurate picture of how a mechanic performs his job and how software might improve that job. The TED team noticed during the first session that the original scope of work was too narrow. There was a whole suite of software that could help the mechanic better perform his job. Third, it established a bond between programmer and soldier. Soldiers could sense that the team was serious and that soldiers' needs would be given serious attention. They were thus eager to cooperate.

4.1.2 Rapid Prototyping.

A prototype is essential for two-way communication. It allows the user to see and touch what the programmer envisions for the user. It gives the user the earliest opportunity to comment on his system, and it gives him some clue as to the potential of the project. The user does not always know what technology is available, and the hands-on experience of the prototype is often the best way educate the user. A prototype serves as a common reference point; without it, not much useful feedback can occur. It also shows how well the programmer understands the user's needs.

4.2 Spiral Model

Boehm's spiral model (Boehm, 1986) incorporates an incremental development schema. Successive prototypes are produced that expand user requirements. In addition, the programmer is able to break complex tasks into smaller components. As each component is developed, it is evaluated against user requirements. The user requirements are re-evaluated as each successive module is developed. Consequently, the user is an integral part of the development team. His or her input is essential.

There are many reasons why the team adopted the spiral method for the TED program. One was the fast paced changes occurring in PC hardware and software. It was an easy guess in 1991 that hardware and software for the PC would continue to improve and become more affordable. Computer memory continues to expand and deflate in price. Hard drives continue to get bigger and cheaper. Screen resolution expands and video cards improve. The price of a Pentium system today rivals the price of a 386 system in 1991. Software

has followed a similar pattern. Every year software improves, new products are announced, and existing products offer upgrades at an astounding pace and more reasonable prices.

The second, and partially related, reason to use an iterative approach is that the user, at the start of a project, can rarely envision how technology can improve his or her job. A system based on initial user expectations will at best be shallow, and may even be useless. The programmer and the SME are each constantly learning about the other. The programmer is continually learning about the needs and duties of the mechanic, and the mechanic is learning about the potential impact of new software on his future.

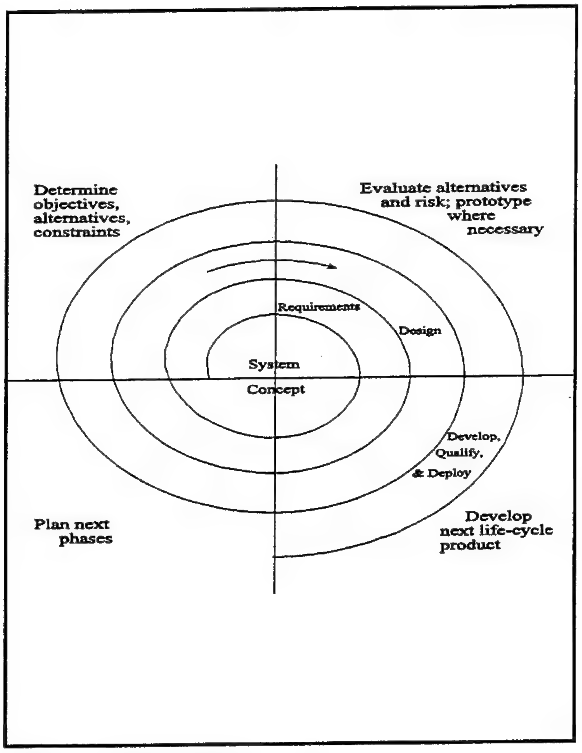

Figure 2: Spiral Model

4.3 Extensive User Involvement

When the aim is to produce software that not only works as planned but also gets used by the mechanic, then user participation in the development process is critical. The TED team heard many stories from soldiers about equipment that never gets used and about equipment that is difficult to use for which a small change would have made the item soldier friendly. To combat these difficulties, TED SMEs were assigned full time to the project. The benefits gained as a result of their early and continued participation were paramount.

4.4 Tracking Hardware and Software Trends

This complements the iterative approach in that goals that were impossible or difficult in the past may now be relatively easy tasks. The TED team continues to meet formally once a month to decide the direction and scope of the project. Unsatisfied goals are re-evaluated, and some may be dropped from the list, while new goals may be added.

4.5 Early and Frequent Testing of Software

In the early years of the project, the software was tested at least weekly using students in the USAOC. After the first formal test in August 1993, the need for testing was relaxed and is now done once a month using students from the USAOC. Additional user feedback is also provided monthly from the National Guard units that have received TED. Feedback from users may lead to small easy changes to the system, or it may lead to new system features or to new software modules.

5. Software Selection.

The Army had already chosen the hardware for TED, the CTS III, which was capable of running Unix, DOS, or Windows. It was clear from the beginning that the project would involve a variety of tasks, each needing a specialized software package. It was also clear that no package could run in isolation. Programs would need to exchange information with others. Windows was chosen as the operating system because of its capabilities and its perceived growth potential.

For any software choice, the key is to choose a package that first meets the user's needs and then, if possible, the programmer's. One choice the programmer must often make is whether to choose commercial off-the-shelf (COTS) packages or whether it is better to write the code him or herself. Today, COTS packages offer many advantages in comparison to code produced in house.

These benefits include

- Cost is reduced by spreading among many.
- Code is already written, saving time.
- Technology proliferation offers many selections.
- External support is available from the developer.

The disadvantages may include

- The program may not fit the problem.
- It is tied to the survivability of the developer.
- While code may initially work, subsequent upgrades may not.
- Possible high run-time fees.

The TED team prefers to use COTS software when available and suitable. Whenever such software is not available or suitable, the choice is to wait until a new product is released or a product upgrade provides the needed functionality, or write the code in house. For example, the current hypertext package was not chosen until the Fall of 1993, and the data base was not selected until the Fall of 1994.

These code decisions are subject to change at each monthly meeting. As the team gathers experience with a package or code, the decision might be to continue as before, to switch from in-house to COTS (or vice versa), or to switch COTS vendors.

6. Reasoning in TED

The main diagnostic software in TED is a Windows-based shell called Adept from SoftSell. Adept is based on a reasoning paradigm called **Procedural Reasoning System** (PRS) (Georgeff and Lansky, 1983 and 1986). PRS is a visual method of encoding reasoning strategies used by expert problem solvers. The knowledge is represented graphically with semantics suited to the procedural, goal-oriented style of problem solving, and PRS is best suited for problems that are both procedural and goal-oriented. A procedural approach uses an ordered step-by-step prescription to obtain a desired result, possibly including alternate paths in case of failure. Such an approach is also goal oriented if some steps are goals to be achieved rather than specific actions to be performed (ADS working paper, 1988).

Army TMs closely follow this paradigm. They are often graphical in nature with decision trees displayed on the page. Some nodes represent goals to be achieved; others represent specific tasks to be performed. These tasks can themselves become goals whose solution is to be given on another page (or in another manual). See Figure 3 for a sample page from the engine manual (TM 9-2835-255-34 Page 3-20).

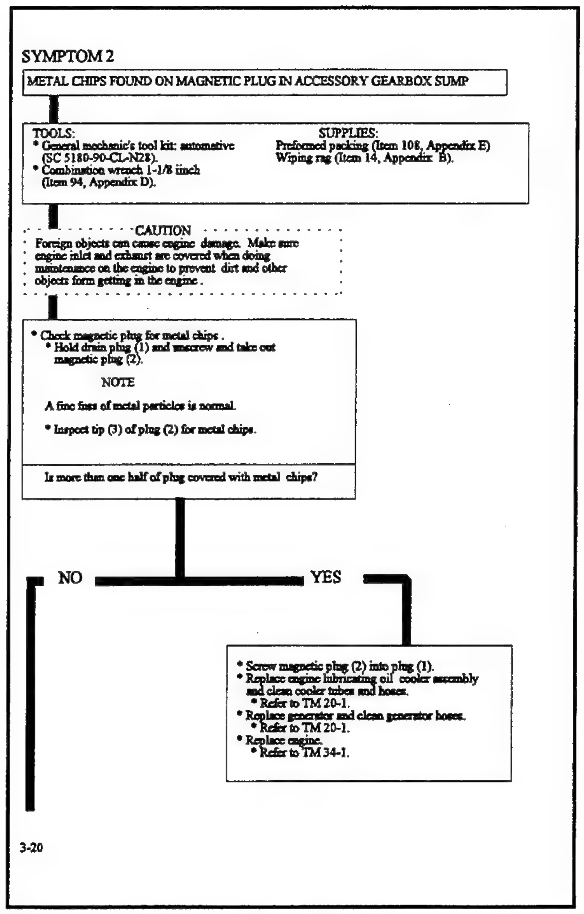

Figure 3: Sample page from TM

PRS combines features from several programming paradigms. Like PROLOG, it has goal-directed inferencing and depth-first search. Like expert system shells, it provides a frame system for global objects. Like LISP, it is well suited for rapid prototyping.

SMEs quickly learned how to read Adept's visual code, and some began writing their own code or modifying code written by the knowledge engineers.

7. TED Software Overview

7.1 Design Goals.

At about 6 months into the project, the SMEs had established several design goals. These goals were based primarily on each SME's extensive experience as an M1 mechanic and as an M1 instructor for engine maintenance classes. The SMEs had much previous experience with soldier mechanics--their likes and their dislikes. The following lists the main design goals for the TED software. The software should be

- accurate,
- easy to use,
- flexible,
- task oriented, and it should
- support multiple levels of expertise.

First, the software should be accurate. It need not be perfect, but it should be significantly better at diagnosing faults than the system it is replacing. Otherwise, it will lose soldier respect and it will not be used. Second, it must be easy to use, for otherwise, it will sit on the shelf. Mechanics have favorite stories of diagnostic equipment that does nothing but occupy lots of storage space. Third, it must be flexible enough to support a variety of diagnostic styles. For example, some mechanics are thorough and methodical, and a structured step-by-step approach is best for them. A few have a sixth sense and "know" what is wrong with an engine. They have only limited need for the information in TED and will only use it as an occasional reference. Other soldiers are a mixture of styles. They may know a lot about some parts of the engine but need guidance in other areas.

The fourth goal is that TED be task structured in a way that is natural for the soldier. The current TMs have a structure that is difficult to use and to follow. Consider the example shown in Figure 3. The task is to determine whether excessive metal chips are present. To perform this check, the user must first find the correct TM, which isTM-34. Once in the right TM, the job is to find the correct page. "Symptom 2, Metal Chips, begins on page 3-20, seen from Figure 3, the tasks for Symptom 2, Metal Chips Found, refer to tasks in TM 20-1 and in TM 34-1." However, little information is given as to which page in TM 20-1 or TM 34-1 to consult. Experts can navigate the TMs, but others find the structure confusing.

The last goal recognizes that mechanics come with different skill levels. Experts need little or no help from TED. Beginners need extensive step-by-step instructions. A system aimed at just one level of expertise would bore the expert and baffle the beginner.

7.2 Soldier Interface.

Users communicate with TED primarily through the mouse, and sometimes through keyboard input. At the top level, TED is menu driven. At this level, the soldier can choose which module to run (described in the next section). Inside a module, TED can be either soldier driven or data driven.

Soldier driven means that TED is in browse mode. This is the equivalent of opening the TM to any section and reading the pages. Browse mode is useful for experts who need little supervision and only occasional help from the TMs.

In data-driven mode, TED first reads its knowledge base to determine engine history and then leads the mechanic through a series of tasks to perform and/or questions to answer. All pertinent information is linked so the user is automatically led through different sections of the TMs, if necessary. The user can leave this mode at any time and go into browse mode.

7.3 A Brief Tour of TED

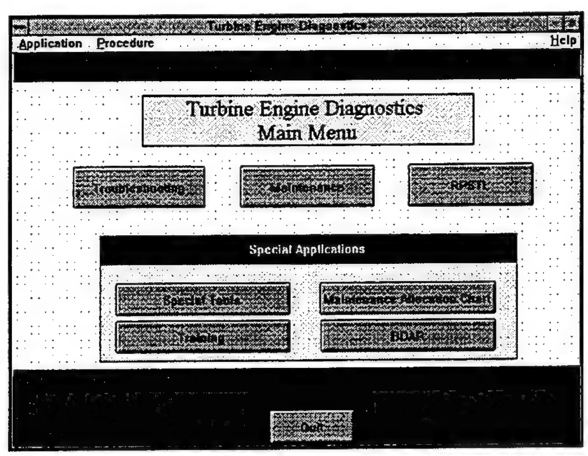

Figure 4: Main Menu Screen

From TED's main menu (see Figure 4), mechanics can access troubleshooting and maintenance tasks. They can also access the repair parts special tool list and special applications such as diagnostic intelligent

tutoring systems (DITS) and automatic breakout box (ABOB). The troubleshooting tasks are further broken into specific areas such as preliminary analysis, troubleshooting by symptom, and protective mode troubleshooting. Each of these features is discussed below.

o Preliminary Analysis (PA). The PA module guides mechanics through a series of detailed inspections of the engine. The engine is divided into separate inspection stations, and at each station, PA guides mechanics through a 100% inspection of that region. It accomplishes this by using graphics, photographs, and an easy-to-read, step-by-step layered instructional format. See Figure 5 for a sample screen. It is designed to assist mechanics with different levels of experience through a series of YES, NO, HOW, and WHY response buttons. Experienced mechanics, who only need to respond to the conditions outlined on the CTS screens, may elect to use YES and NO buttons. Inexperienced mechanics, who require additional guidance, may elect to use HOW and WHY buttons. The HOW and WHY logic is layered, so that successive invocation of HOW will lead to more detailed explanation than given at the previous level. Upon completion, an electronic DA Form 2404 with noted deficiencies is automatically generated. When deficiencies are noted, TED automatically links to pertinent sections of maintenance and repair parts modules.

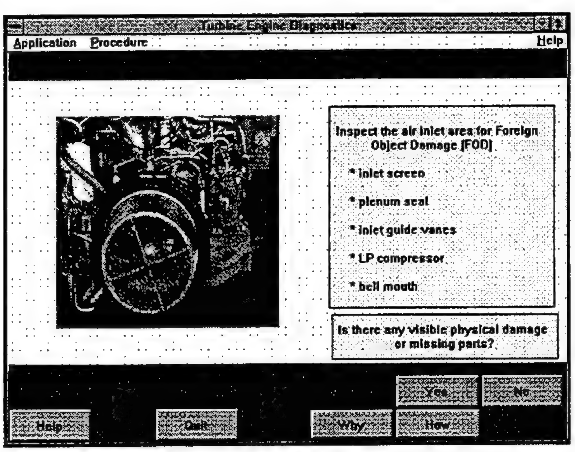

Figure 5: Preliminary Analysis Screen

o Rapid Functional Assessment (RFA). The RFA module is a safety procedure to quickly determine whether it is safe to attempt to start the engine. A minimal number of inspections--three rotational and four lubricational--evaluate the mechanical integrity of the engine's internal rotating components. RFA is an important safety check because it minimizes the potential for personal injury or unnecessary damage to the engine.

o Troubleshooting by Symptom. Troubleshooting by Symptom opens a new menu screen that organizes DS diagnostic logic by terms easily recognized by mechanics, regardless of experience. Symptoms include: no start, low power, high oil consumption, engine smokes, metal contamination, quick coast down, idle faults, and engine shutdown. Each of the eight submodules contains diagnostic logic to first determine the cause of the faulty symptom, and once the cause has been detected, TED will link to the appropriate maintenance and repair parts modules.

o Protective Mode (PM) Troubleshooting. The ECU constantly monitors all sensor inputs and compares them with the engine's established parameters. If an input is out of tolerance, the ECU initiates one of four protective mode actions to prevent damage to the engine. Unfortunately at DS, there is currently no way to query the ECU to find what protective mode, if any, has been invoked. The PM module first checks whether a PM condition exists and if so, checks for the cause, and then links to the appropriate maintenance and repair parts modules.

o Maintenance Procedures. Maintenance actions for any component include adjust, repair, remove, and replace. The procedures can be invoked in either browse mode or data-driven mode. When in browse mode, maintenance procedures are manually selected through menus and submenus. This provides experienced mechanics the flexibility of viewing only the procedures that they need, while bypassing familiar or routine tasks. When in the data- driven mode, TED automatically establishes the correct links to all pertinent maintenance procedures (and to sections of the repair parts manual). The maintenance tasks detail applicable procedures from TM 9-2835-255-34 series.

o Repair Parts Special Tool Listing (RPSTL). In lieu of paper RPSTLs (TM 9-2350-264-24P1, TM9-2520-276-34P, and TM 9-2835-255-34P), the TED RPSTL is electronically generated. All required information is provided so that parts can be automatically ordered and filed to the parts request, which can then be exported to a printer.

8. Formal User Test

During the week of 15 to 21 August 1993, an initial field test of the TED program was conducted at Fort Stuart, GA. Participating in the test were 30 soldiers from the Support Squadron, 278th Armored Cavalry Regiment and 771st Maintenance Company, 176th Maintenance Battalion of the Tennessee Army National Guard (TNARNG). Keeping in mind the target audience (DS mechanics), the test had two objectives: first, measure how accurately and quickly mechanics could identify randomly assigned faults on the engine using TED versus using TMs; second, decide if the program was soldier friendly. For the test, the 30 mechanics were divided into 3 levels of 10 mechanics each: E1-E4, E5, and E6-E7. Because the TNARNG had just transitioned to the MBT, there was a lack of experience on the engine. The test was designed by Dr. Malcolm Taylor, Chief Statistician, ARL, and the late Dr. Henry Tingey, University of Delaware. The field test was developed to test the preliminary analysis and no-start modules of the TED program.

Each mechanic inspected two engines, one with TED and one with the TMs. The engines had a random number of faults installed from a randomized list of possible faults. There was a 1-hour time limit for each inspection. An observer, with a score card, was present with each mechanic to log faults and the times that each fault was located. The conditions of the test approximated the actual working environment of the mechanics:

- A DS maintenance bay and GHSS were available.

- TED or TMs were made available to the mechanics.

- Instructions to each mechanic were to inspect the engine and determine the fault causing a no-start condition. Observers provided no other assistance to the mechanics.

- An unrealistic, yet necessary condition,required mechanics to be situated so that they worked independently without any intercommunications.

Three types of data were collected during the field test: first, the observer's score card (mentioned previously), which served as the basis for the statistical analysis; second, a questionnaire completed by each mechanic, which allowed him to express his impressions of TED; third, each observer recorded personal comments, which served as an additional source of information for further revisions.

PRELIMINARY RESULTS. Although the TNARNG soldiers had very little engine experience, the field test results show a definite trend. At each level, TED outperformed the current TM procedures (see Table 1). TED assisted the junior enlisted and the junior noncommissioned officers in finding at least **twice as many faults** as compared to the TMs. Note that even though TED is designed for junior mechanics, senior mechanics were able to increase their efficiency by using TED. Overall, the mechanics demonstrated a 96% increase in their ability to efficiently diagnose the engine.

RANK	MANUAL FAULTS DETECTED	TED FAULTS DETECTED
E1 - E4	26%	52%
E5	11%	42%
E6 - E7	42%	56%
OVERALL	26%	51%

Table 1: Preliminary Test Results

The ease of use became readily apparent to the observers during the initial training session. Because many of the mechanics had never used a computer, the observers allocated a 1-hour training block for each mechanic. In less than 10 minutes, mechanics who had never used a computer were effectively maneuvering through the software and hardware. Soldier acceptance was also unanimously positive. Both computer- and noncomputer-literate mechanics readily accepted TED as the preferred tool for maintaining the engine. Listed next is a sample of the soldiers' comments:

o "TED is easy to use and understand."

o "TED is easy to use. It'll be very helpful to both experienced and nonexperienced mechanics."

o "I like the specific guidance that it provides; it makes it easy to solve problems."

o "I like how it breaks down the components and explains each of them; it provides a structured procedure."

o "This will cut the TI (Technical Inspection) time dramatically; it pinpoints the areas very well. It saves time; it's accurate, compact, and easy to use."

o "Regardless of experience, one could use TED."

o "It is easier than using the Tms."

o "TED is my buddy."

9. Related Efforts

Two other features that are linked to the TED program include the diagnostic intelligent tutoring system (DITS) and the ABOB. Although initially separate projects, both have come to live under the TED umbrella and become integral parts of TED.

DITS is an embedded tutorial that covers basic maintenance procedures, theory of engine operations, and guidance in such tasks as connecting the GHSS and using a multimeter. Using interactive review and troubleshooting modules, mechanics can hone their diagnostic skills in a field environment. DITS, a diagnostic trainer, complements TED, a diagnostic tool, by providing mechanics a complete system.

The ABOB, developed by Dr. Mark Kregel from ARL, is an automated version of the breakout box (BOB), which is a diagnostic tool that is currently in the field. Mechanics employ the BOB, connected to the vehicle's electronic control unit, as an alternate troubleshooting method to determine the operational status of the engine. The ABOB automates the manual tasks associate with the BOB by providing instantaneous access to all of the engine's voltage signals.

The ABOB contains an electronic circuit capable of reading 128 channels in a fraction of a second. These signals are passed to the CTS through a standard serial port. The ABOB can be used with or without TED to display voltages on the CTS screen in either numerical or graphical format. When TED is run with the ABOB, signals can be automatically monitored, and when a fault occurs, mechanics will be notified of the problem.

10. Future Efforts

Future improvements of the TED program include the incorporation of approximate reasoning methods to allow better representation and integration of sensor data. Before the TED program, in particular the invention of the ABOB, the ability to monitor more than a single sensor reading on the MBT engine did not exist. More important, the ability to determine correlations between changing sensor information and the possible inference of diagnostic and/or prognostic information did not exist. This area lends itself to research in the application of fuzzy logic and neural nets.

11. References

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